

This Page Is Inserted by IFW Operations  
and is not a part of the Official Record

## **BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS
- TEXT CUT OFF AT TOP, BOTTOM OR SIDES
- FADED TEXT
- ILLEGIBLE TEXT
- SKEWED/SLANTED IMAGES
- COLORED PHOTOS
- BLACK OR VERY BLACK AND WHITE DARK PHOTOS
- GRAY SCALE DOCUMENTS

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning documents *will not* correct images,  
please do not report the images to the  
Image Problem Mailbox.**

C99



Consommation et  
Affaires commerciales Canada  
Bureau des brevets  
Ottawa, Canada  
K1A 0C9

Consumer and  
Corporate Affairs Canada  
Patent Office

(11) (C) 2,015,460  
(22) 1990/04/26  
(43) 1991/10/26  
(45) 1993/12/14  
(52) 166-33

5,079,3/96

<sup>5</sup>  
(51) INTL.CL. E21B-043/16

(19) (CA) CANADIAN PATENT (12)

(54) Process for Confining Steam Injected Into a Heavy Oil  
Reservoir

(72) Kisman, Kenneth E. , Canada

(73) Alberta Oil Sands Technology and Research Authority ,  
Canada

(57) 5 Claims

Canada

CCA 3254 (10-92) 41 7530-21-028-3254

2015460

1                   "PROCESS FOR CONFINING STEAM INJECTED INTO  
2                   A HEAVY OIL RESERVOIR"

3                   ABSTRACT OF THE DISCLOSURE

4                   The process is practised in the context of a first  
5                   pattern of wells completed in a first portion of a heavy oil  
6                   reservoir. The first pattern has undergone steaming and  
7                   production and the underlying reservoir portion is significantly  
8                   depleted. A second pattern of wells is completed in a second  
9                   less-depleted portion of the reservoir. The two reservoir  
10                  portions are adjacent and in fluid communication. This may be  
11                  through a laterally extending thief zone high in the reservoir,  
12                  the thief zone having higher permeability to steam than the main  
13                  body of the reservoir. Steam injected into the second portion  
14                  thus will be lost into the depleted portion. The process  
15                  comprises injecting non-condensable gas into the depleted portion  
16                  while steaming and producing oil from the less-depleted second  
17                  portion. The gas is injected at a rate sufficient to maintain  
18                  the pressure in the two reservoir portions about equal. As a  
19                  result, the loss of steam to the depleted portion is inhibited.

2015460

4/1

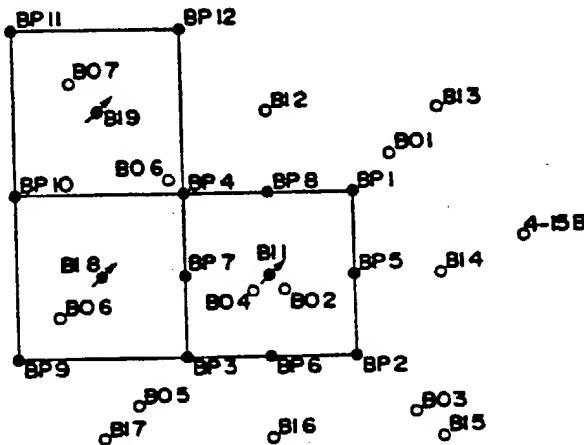
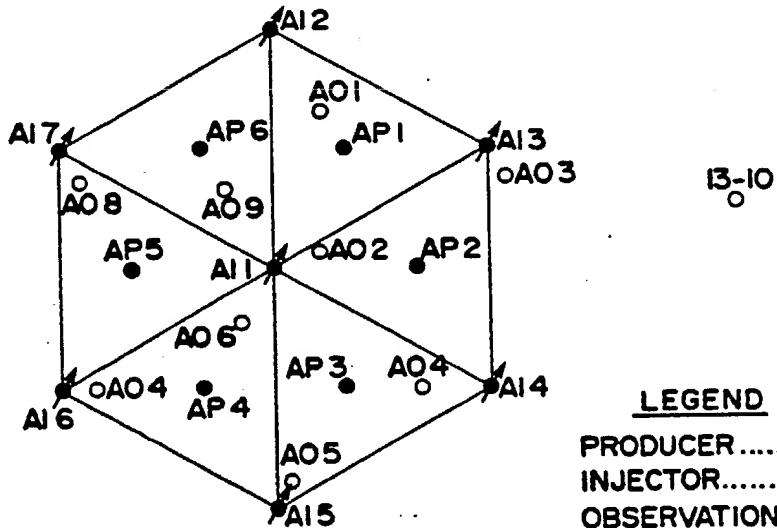


Fig. 1

4-15C



B

2015460

4/2

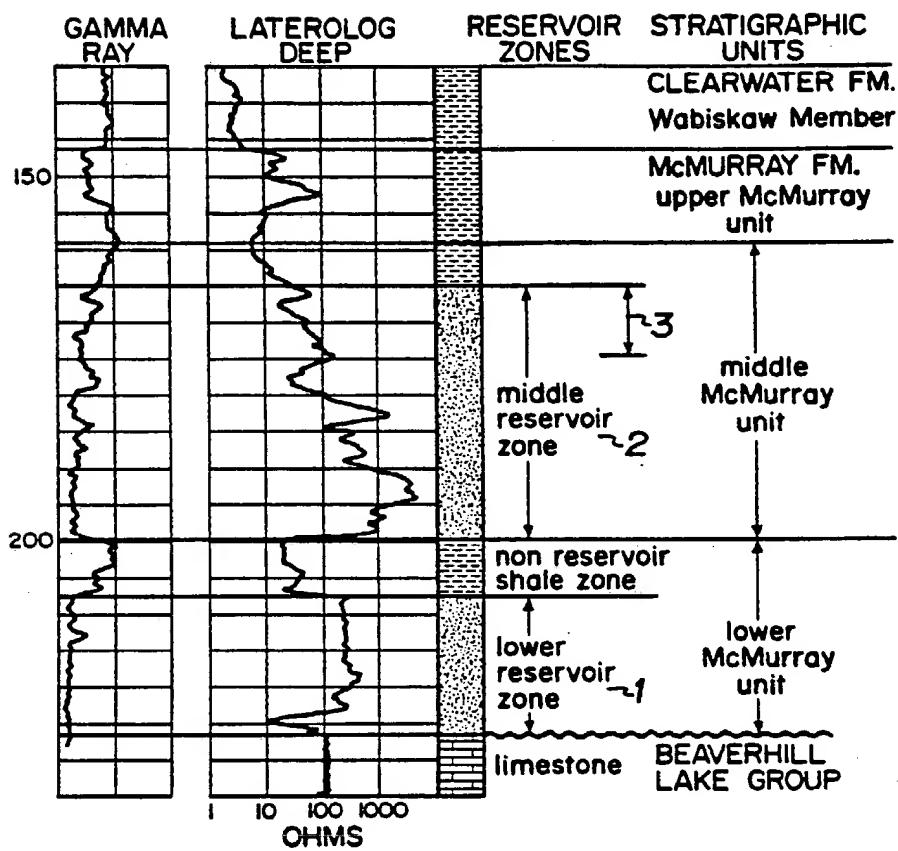


Fig. 2.

B

2015460

4/3

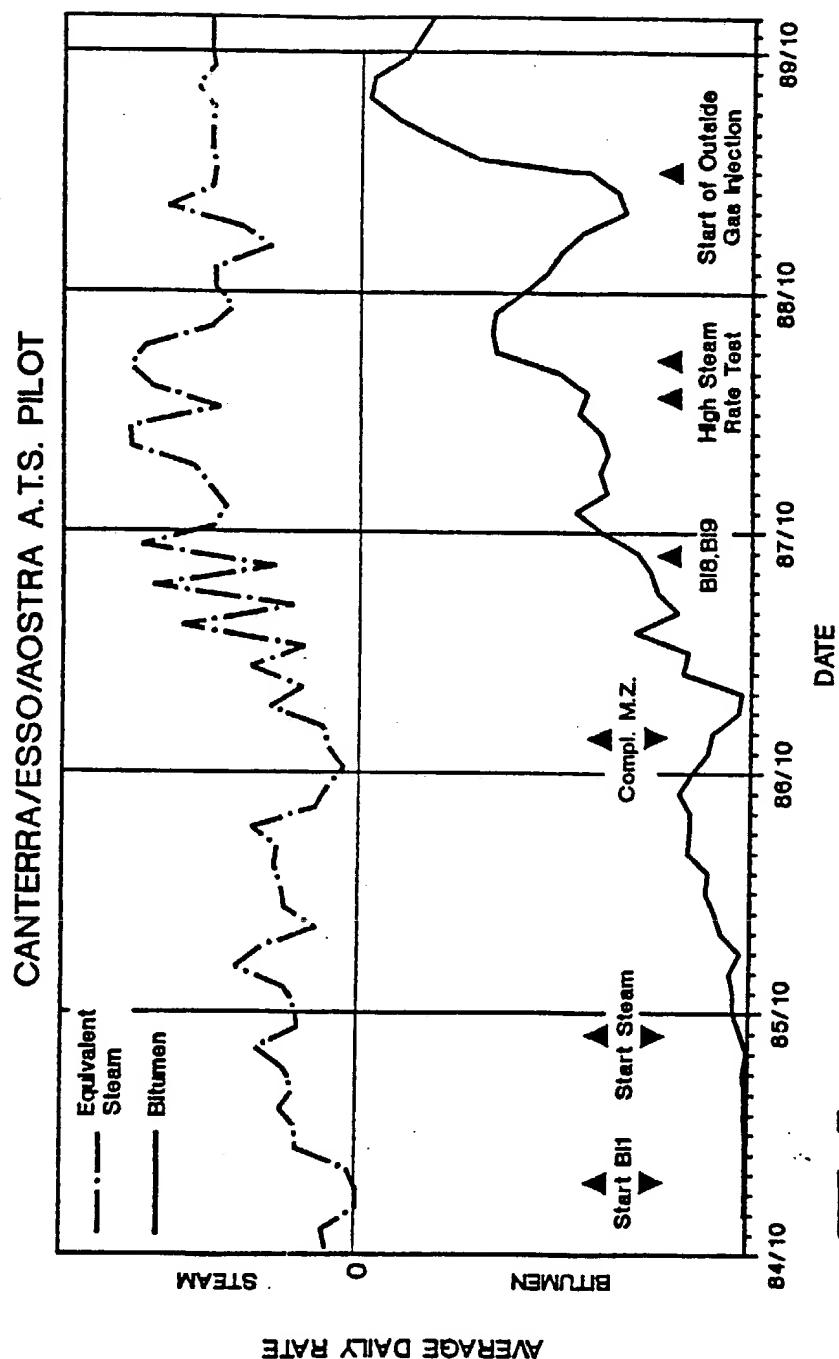
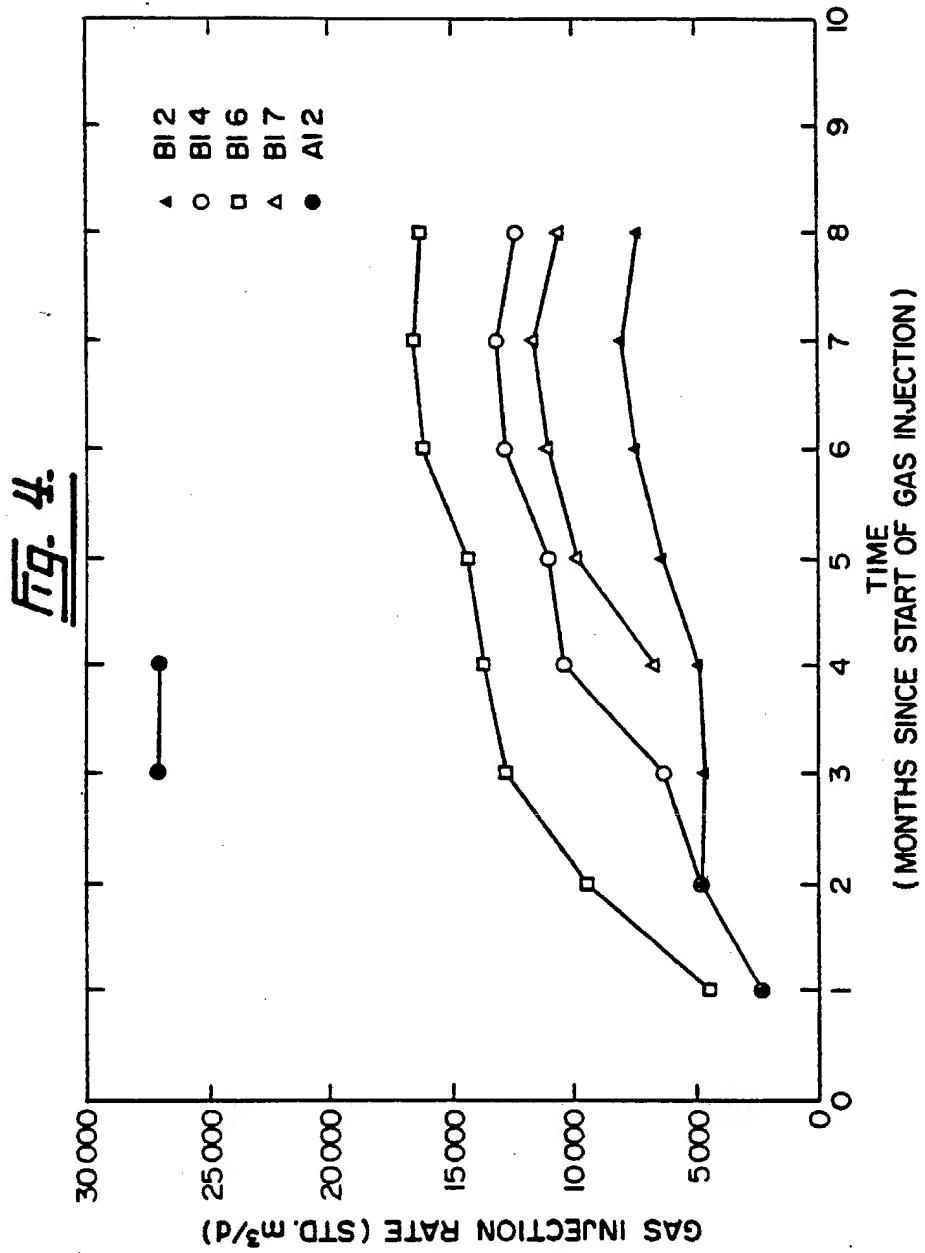


Fig. 3.

B

2015460

4/4



1                   Field of the Invention

2                   This invention relates to an improvement of a steam  
3                   injection process for the recovery of heavy oil. More  
4                   particularly, it relates to injecting non-condensable gas into  
5                   a depleted portion of a reservoir to pressure it up and prevent  
6                   the escape of steam thereinto, which steam is being injected into  
7                   an adjacent portion of the reservoir.

8                   BACKGROUND OF THE INVENTION

9                   It is conventional practice to inject steam into a  
10                  heavy oil reservoir to heat the formation and reduce the  
11                  viscosity of the oil, thereafter producing the oil once its  
12                  mobility has been improved. Such an operation is commonly  
13                  referred to as a "thermal project".

14                  A problem can arise with respect to a thermal project  
15                  if a "thief zone" is in communication with the oil reservoir into  
16                  which the steam is being injected. If this is the case, the  
17                  injected steam will preferentially move into the thief zone.  
18                  Heating of the oil-saturated portion of the reservoir is then  
19                  reduced.

20                  Frequently the thief zone is a laterally extending  
21                  section of that portion of the oil-containing reservoir that is  
22                  to be heated. The section typically will have a relatively high  
23                  gas or water saturation. Often it is located at the top of or  
24                  high in the reservoir.



2015460

1       A thief zone can also occur in another manner. In  
2 heavy oil thermal projects it is common procedure to practice  
3 steam injection and oil production in a first area and, when the  
4 reservoir underlying the area is significantly depleted, to then  
5 expand the project by commencing operations in an adjacent second  
6 area. In some cases, the depleted first portion of the reservoir  
7 is in fluid communication with the non-depleted second portion  
8 of the reservoir. In this situation, steam injected into the  
9 non-depleted portion of the reservoir may migrate into the  
10 depleted portion. As a result, the depleted first portion of the  
11 reservoir constitutes a thief zone for steam being injected into  
12 the second portion.

13       When steam escapes into such a thief zone, it is found  
14 that injection pressure diminishes and the temperature in the  
15 producing portion of the reservoir is relatively low. As a  
16 result, the oil production rate also drops off.

17       There is therefore a need for a process that will  
18 inhibit losses of injected steam through or into a thief zone.

19                    SUMMARY OF THE INVENTION

20       This embodiment of the invention is concerned with a  
21 situation where there are two adjacent steam injection and fluid  
22 production patterns, both completed in the same reservoir. The  
23 reservoir portion underlying the first pattern has already  
24 experienced some steam injection and oil production. Thus it is

1 partially depleted. The reservoir portion underlying the second  
2 pattern has experienced less depletion. There is fluid  
3 communication between the patterns - stated otherwise, steam  
4 injected through the wells of the second pattern will enter the  
5 more depleted reservoir portion.

6 In accordance with the invention, non-condensable gas  
7 is injected through wells of the first pattern into the more  
8 depleted reservoir portion at the same time that steam is  
9 injected through wells of the second pattern. Preferably the  
10 non-condensable gas is injected at a rate and in an amount  
11 sufficient to substantially equalize the pressure in the more  
12 depleted reservoir portion with the pressure in the steam zone  
13 in the second reservoir portion. When this is done, steam loss  
14 into the more depleted portion of the reservoir is inhibited with  
15 a concomitant improvement in oil production and steam/oil ratio  
16 at the second pattern. The gas injected into the first pattern  
17 may also contribute to improved performance in the production  
18 wells within the first pattern.

19 DESCRIPTION OF THE DRAWINGS

20 Figure 1 is a schematic showing the patterns and the  
21 gas injection wells which were used in demonstrating the  
22 invention at a pilot project;

23 Figure 2 illustrates with logs the nature of the  
24 reservoir in the pilot test area;

2015460

1       Figure 3 is a plot showing steam injection and bitumen  
2    production rates for the B pattern of the pilot test. Arrows on  
3    the plot indicate when the injection well BI1 was started up,  
4    when BI1 injection was switched from hot water to steam, when the  
5    middle zone was completed, when injection wells BI8 and BI9 were  
6    started up, when the high steam rate test was conducted, and when  
7    outside gas injection began; and

8       Figure 4 is a plot of gas injection rate through the  
9    wells identified on the plot.

10                    DESCRIPTION OF THE PREFERRED EMBODIMENT

11               The invention is exemplified by the following example  
12    based on a pilot test conducted in the Kearn Lake region of  
13    Alberta.

14               The reservoir at the pilot site, depicted in Figure 2,  
15    has two oil producing pay zones, a lower zone 1 and a middle zone  
16    2. The middle pay zone 1 is approximately 35 m thick and has a  
17    sand region 3 at its upper end. This region 3 is approximately  
18    10 m thick and has significantly higher water saturation than the  
19    pay zone 2. The region 3 constitutes a thief zone for steam  
20    injected through well perforations in the pay zones 1,2.

21               The bitumen in the pay zone 2 is effectively immobile  
22    at initial reservoir conditions.

23               A steam drive pilot was initiated in an A pattern  
24    consisting of steam injection wells and production wells. The  
25    layout of the A pattern wells is shown in Figure 1. Each well

1 is identified as to pattern (A), nature (injection (I),  
2 production (P), or observation (O)) and number. The A pattern  
3 was an inverted 7-spot with peripheral steam injection to enclose  
4 the pattern and make it equivalent to an inner pattern in a  
5 commercial project. The pattern covered 5.37 acres.

6 At the same time that the A pattern was drilled, an  
7 adjacent B pattern was also drilled. The B pattern was  
8 originally an inverted 5-spot surrounded by 8 steam injection  
9 wells. It was decided to delay start-up of the B pattern to gain  
10 operating experience on the A pattern.

11 A steam drive was initiated in December, 1981, in the  
12 A pattern and continued for 5 years. Steam was injected into the  
13 AI wells and fluid was produced from the AP wells.

14 It became clear that a large volume of steam was being  
15 lost from the A pattern, as the steam-oil ratio was very high.

16 As a result of the A pattern experience, changes were  
17 made to the B pattern prior to its start-up. It was decided not  
18 to inject steam into the peripheral wells of the B pattern.  
19 Instead the B pattern was converted from a 5-spot to a 9-spot.

20 Start-up of the BI1 pattern occurred in February, 1985,  
21 and start-up of the patterns of BI8 and BI9 was initiated in  
22 September, 1987. Steam was injected through the 3 injection  
23 wells and fluid produced from the 12 production wells in  
24 conventional fashion.

25 Wells BI2, BI3, BI4, BI5, BI6 and BI7 were also  
26 completed in the reservoir as observation wells and were used to  
27 monitor temperature and pressure outside the B pattern.

1        The chronology of operations in the B pattern and the  
2        effect on bitumen production is shown in Figure 3.   Hot water  
3        injection was initiated into the lower zone 1 of the BI1 pattern  
4        in February, 1985.   Steam injection into the lower zone 1 of the  
5        BI1 pattern began in August, 1985.   Middle zone 2 operations  
6        began in December, 1986.   The BI8 and BI9 patterns were added in  
7        September, 1987.

8        A high rate steam test was conducted in the summer of  
9        1988 in which the steam injection rate was approximately doubled  
10      for a period of about two months.

11      The outside gas injection test was begun in April,  
12      1989, with the injection of natural gas into wells BI2, BI4 and  
13      BI6 following perforation of those wells in the region 3 of the  
14      middle zone 2.   Gas injection into wells BI7 and AI2 was  
15      initiated a few months later, as shown in Figure 4.

16      As shown in Figure 3, the high rate steam test resulted  
17      in a significant increase in bitumen production rates, but the  
18      steam-oil ratio did not improve.

19      After the high rate steam test, the bitumen production  
20      rate fell considerably until March, 1989, when the steam  
21      stimulation of some production wells began in anticipation of  
22      the outside gas injection test.

23      As stated, the outside gas injection test began in  
24      April 1989, and is still continuing.   Gas injection was conducted  
25      simultaneously with steam injection.   More particularly, during  
26      the outside gas injection test, the steam injection rate was held  
27      constant at a rate of only about 60% of that during the high rate  
28      steam test.   The bitumen production rate during the outside gas  
29      injection test

1 started to increase significantly within one month, and, over the  
2 eight month period since gas injection began, the bitumen  
3 production rate has, on average, been more than 80% higher than  
4 that prior to gas injection.

5 The instantaneous steam-oil ratio during the outside  
6 gas injection test also improved considerably over that observed  
7 prior to outside gas injection.

8 No detrimental effects of outside gas injection have  
9 been observed. There has been no noticeable increase in gas  
10 production at the production wells. The injected gas remains  
11 near the top of the payzone 2 due to gravity effects, while  
12 liquids are produced through perforated intervals near the base  
13 of the pay zone.

14 Prior to outside gas injection, the region 3 allowed  
15 fluids to flow out of the B Pattern. In particular, steam, hot  
16 water and hot bitumen flowed out of the B pattern during steam  
17 injection within the pattern. This was evidenced by temperature  
18 and pressure measurements at the observation wells outside the  
19 pattern and by the fact that the pressure within the pattern  
20 remained low. When the steam injection rate was increased in the  
21 B pattern, a temperature response could be detected even within  
22 the A pattern. Thus the A pattern constituted a thief zone in  
23 communication with the B pattern.

24 At the time gas injection began into region 3 through  
25 wells outside the B pattern, the pressure within the B pattern  
26 was only about 800 kPa. The native reservoir pressure is about

1       300 kPa. Within three months of the commencement of outside gas  
2       injection, the pressure within the B pattern increased from 800  
3       kPa to over 1000 kPa and the pressure within the A pattern  
4       increased from about 400 kPa to over 900 kPa. Within the B  
5       pattern, the temperature increased along with the pressure as  
6       determined by saturated steam conditions within the B pattern.

7               Prior to and during the outside gas injection  
8       operation, wells AP1 and AP3 and AP6 were maintained on  
9       production even though no steam was injected into any wells in  
10      the A pattern. Prior to the commencement of outside gas  
11      injection, the A pattern wells benefitted from heat communication  
12      with the B pattern but this heat communication was eliminated  
13      when gas injection began. Even though the A pattern wells lost  
14      heat communication, the production performance of wells AP1, AP3  
15      and AP6 has increased over that prior to gas injection. This  
16      increased production is believed to be related to an improved  
17      gravity drainage mechanism due to the increased gas saturation  
18      in the A pattern.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE  
PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A method for recovering heavy oil that is effectively immobile at reservoir conditions, from a reservoir having a partially-depleted portion penetrated by a first pattern of wells and an adjacent less-depleted portion penetrated by a second pattern of steam injection and oil production wells which are completed in said less-depleted portion, the less-depleted portion of the reservoir being in fluid communication with the partially-depleted portion, comprising:

injecting steam into the less-depleted portion of the reservoir through the injection wells of the second pattern, to heat the oil in said portion and render it mobile;

simultaneously injecting non-condensable gas, through at least one well of the first pattern, into the partially-depleted portion of the reservoir at a rate and in an amount sufficient to maintain the pressure in the partially-depleted portion at the gas injection wells about equal with the pressure in the reservoir portion underlying the second pattern and undergoing steam injection; and

producing heated oil from the second pattern.

2. The method as set forth in claim 1 wherein:

the non-condensable gas injected is selected from the group consisting of natural gas, flue gas and carbon dioxide.

2015460

3. The method as set forth in claim 2 wherein:  
the production wells of the second pattern are  
perforated low in the payzone of the reservoir.

4. The method as set forth in claim 3 wherein:  
the reservoir portions are in fluid communication  
through a thief zone high in the reservoir.

5. The method as set forth in claim 1 wherein:  
the reservoir portions are in fluid communication  
through a thief zone high in the reservoir; and  
steam and gas injection are continued simultaneously  
after heat breakthrough at the production wells of the second  
pattern.